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## **French Modular Artillery BCM and TCM Charge System for 155 mm**



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## **Abstract**



French companies GIAT Industries and SNPE are developing a 155 mm modular artillery charge systems fully compatible with mechanical autoloading systems and matching the NATO Joint Ballistic Memorandum of Understanding.

Charges system concern bottom and top charges as BCM and TCM for covering zones 1 to 6 in 155 mm 52 calibres gun.

In this paper we describe at first the design of the charges and the results from loading, firing, and environmental tests.

This modular artillery charge system developed by GIAT Industries and SNPE teams is fully interoperable with all NATO 155 mm ordnance including autoloader systems and in particular French CAESAR truck-mounted artillery system or the French 155 AUF2 self-propelled artillery system with fully automated handing and loading both for charge and shell.

## French modular artillery BCM and TCM charge system for 155 mm

TCM charges design was chosen among compositions and geometries described in 1994 at 6th Gun Propellant symposium in Parsippany.

During the development, different solutions were tested :

- gun propellant composition for energy, nb of perf for progressivity, geometrie for loading
- combustible case composition for combustibility and mechanical performances
- igniters for functioning, pressure waves, action time

In this paper propelling charge use

kerfed sticks and either NC/TEGDN/NQ/RDX or NC/NGL composition with 19 or 7 perfs,

fully combustible containers comprising only two pieces made by beater additive felting process, one body and cap closer,

ignitor device solution consolidated black powder allow an axis free volume centre core for better spreading.

## **French modular artillery BCM and TCM charge system for 155 mm**



Firing results with TCM charges show full agreement with specifications for velocity, max pressure, temperature coefficient, pressure waves except for gun tube erosion for zone 6.

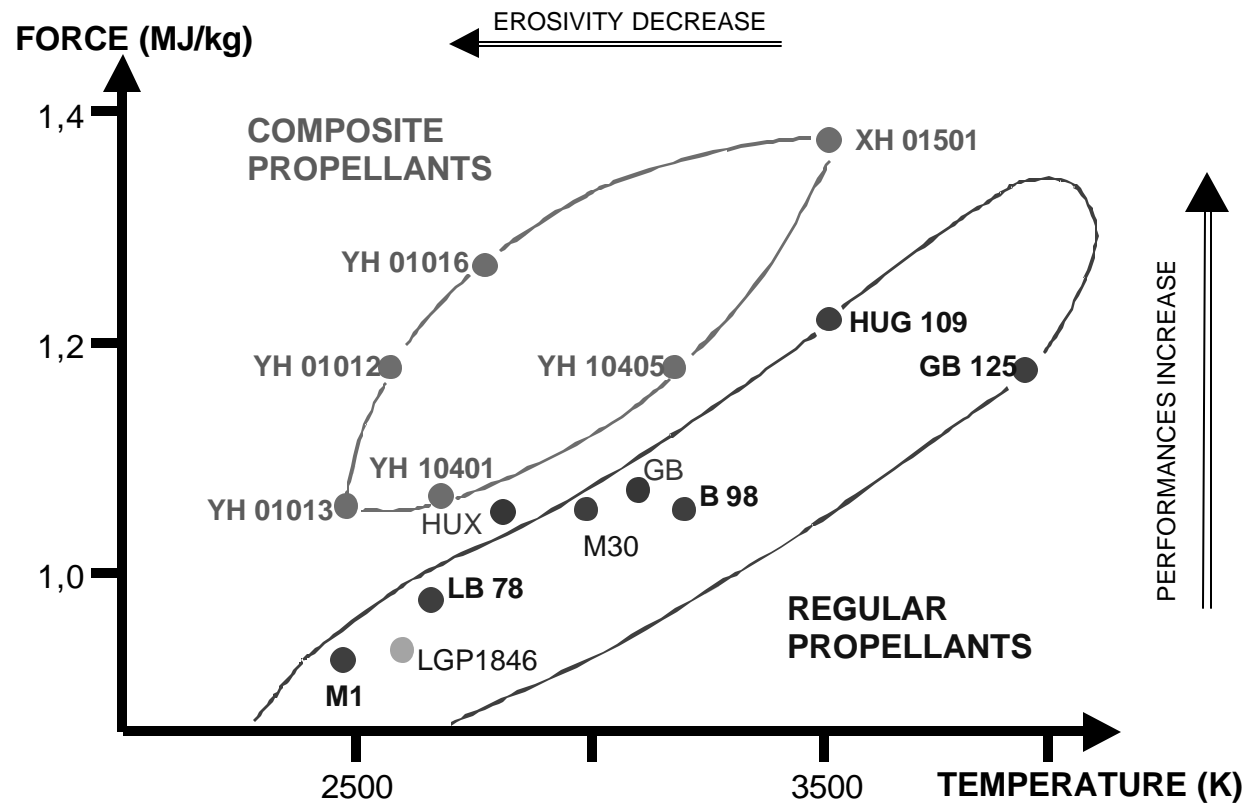
In addition charges were tested for shelf life including migration of NEEP, vulnerability and automatic loading solicitation withstanding.

For low zone BCM charges keep the key design of TCM charges but are distinguishable by colour and by shape. The charge is filled with single base grain gun propellant and use a modified igniter but still consolidated black powder.

## Stick propellants geometries for higher performances

	Slotted tube	Tube	7 P Kerfed	19 P Kerfed	19 P Kerfed
Internal diameter (mm)	0.5	1.5	0.5	0.5	0.3
Initial velocity (m/s)	900	931	957	978	986
Propellant weight (kg)	13.480	14.710	15.800	16.700	17.300
Web size (mm)	3.4	3.3	2.9	3.0	3.1
External diameter (mm)	7.3	8.1	13.1	19.56	19.19
Stick number	314	252	93	43	45
1 stick surface area	41.66	49.76	133.41	296.76	287.88
Total stick surface area	13081	12540	12407	12761	12955
Case surface area without igniter with igniter	17671 (mm <sup>2</sup> ) 17181 (mm <sup>2</sup> )				
Porosity without igniter with igniter	0.260 0.239	0.290) 0.270	0.298 0.278	0.278 0.257	0.267 0.246
Stick length (mm)	107	122	133	136	139

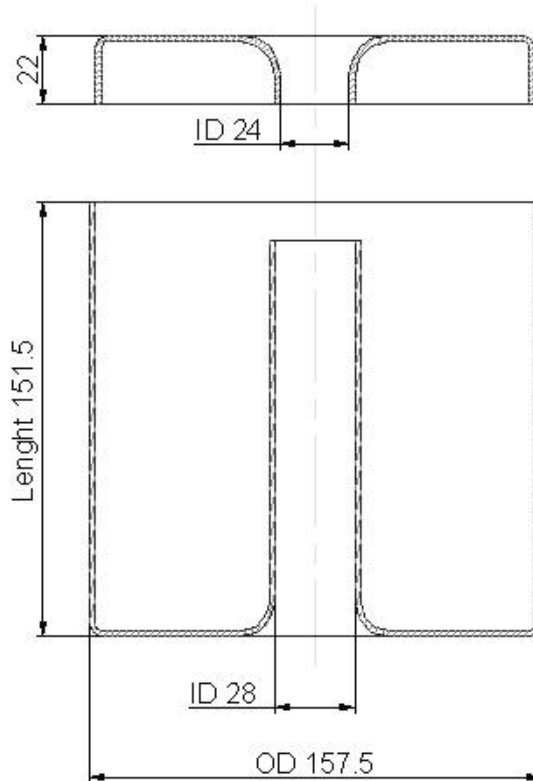
## Stick propellants compositions for higher performances



## TCM composition candidates

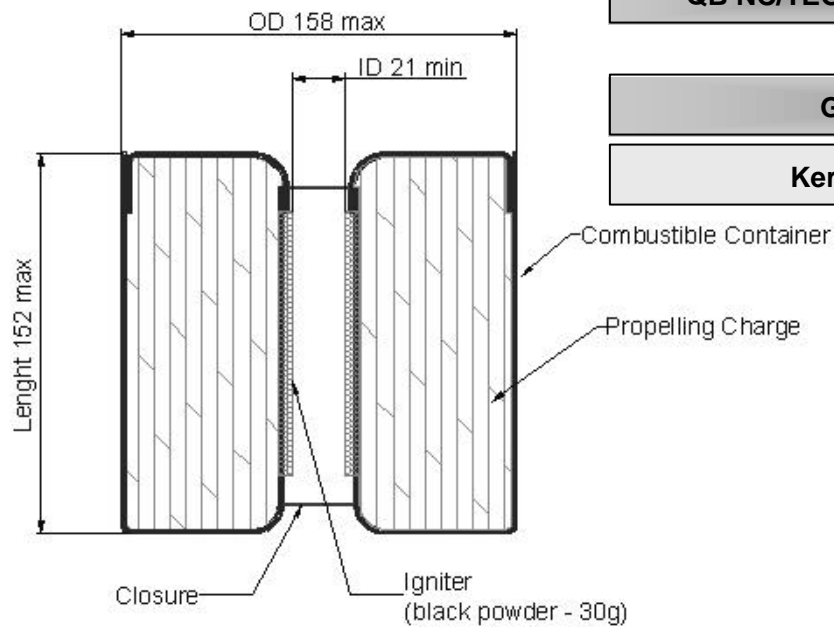
Gun propellant	Composition	Impetus (MJ/kg)	Te (K)	Nb mole/g	g	r (g/cm <sup>3</sup> )
HUX TEGDN QB	NC: 52.3 TEGDN: 26.1 RDX: 10.6 NQ: 8.5 CNT: 1.1 div: 1	1.065	2820	44.6	1.25	1.57
GB93' DB	NC: 56.6 NGL: 34.4 DEP: 4.3 CNT: 3.5 div: 1.7	1.079	3112	41.14	1.237	1.58
HUX DEGDN' QB	NC: 35 DEGDN: 23 RDX: 10 NQ: 30 CNT: 1.1 div: .8	1.07	2847	44.42	1.245	1.62
M30 TB	NC: 27.9 NGL: 22.4 NQ: 46.8 CNT: 1.5 div: 1.4	1.076	2994	43.21	1.244	1.68

## TCM design - Combustible container



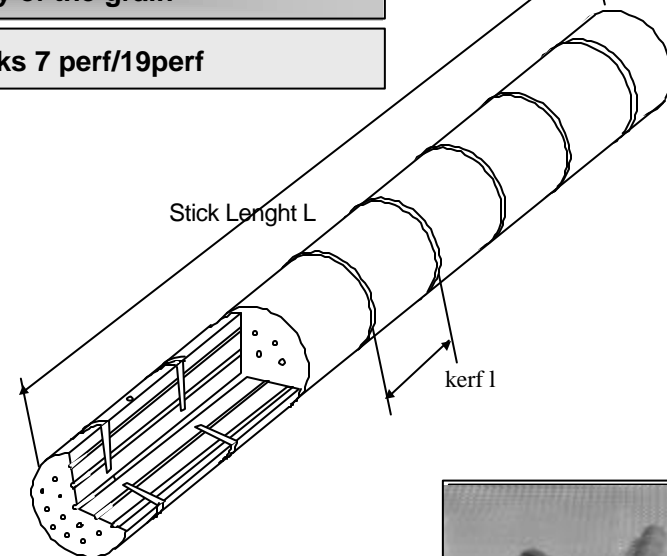
Composition of felted materials		
Nitrocellulose	68 %	60 %
Cellulose	26 %	23 %
Resin binder	5 %	8 %
Stabilizer (DPA)	1 %	1 %
Wear reducing agent (TiO <sub>2</sub> )	-	8 %

# TCM design - propelling charge

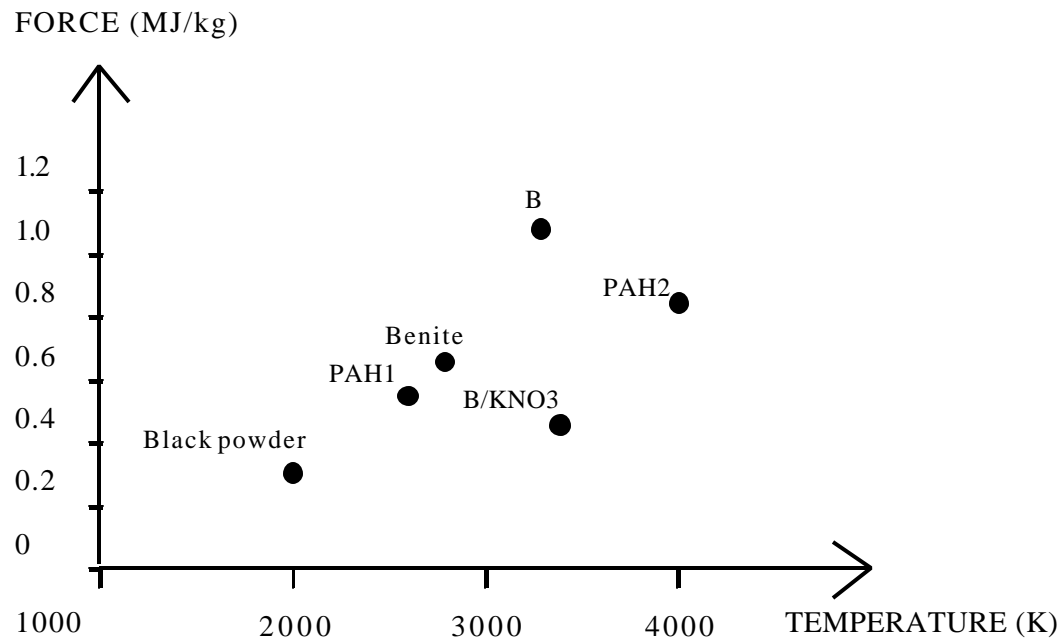


Composition of igniter	
Consolidated Black powder	100 %
weight	30 g

Composition of propellant	
DB NC/NGL	56.5/34.8
QB NC/TEGDN/NQ/RDX	52/26/8.6/10.7
Geometry of the grain	
Kerfed sticks 7 perf/19perf	



## Ignition compositions performances



**Black powder was selected for smooth and efficient ignition properties**

## TCM firing test results in 155 52 calibres for 6 modules

muzzle velocity 945 m/s at 21°C is obtained under charges conditions

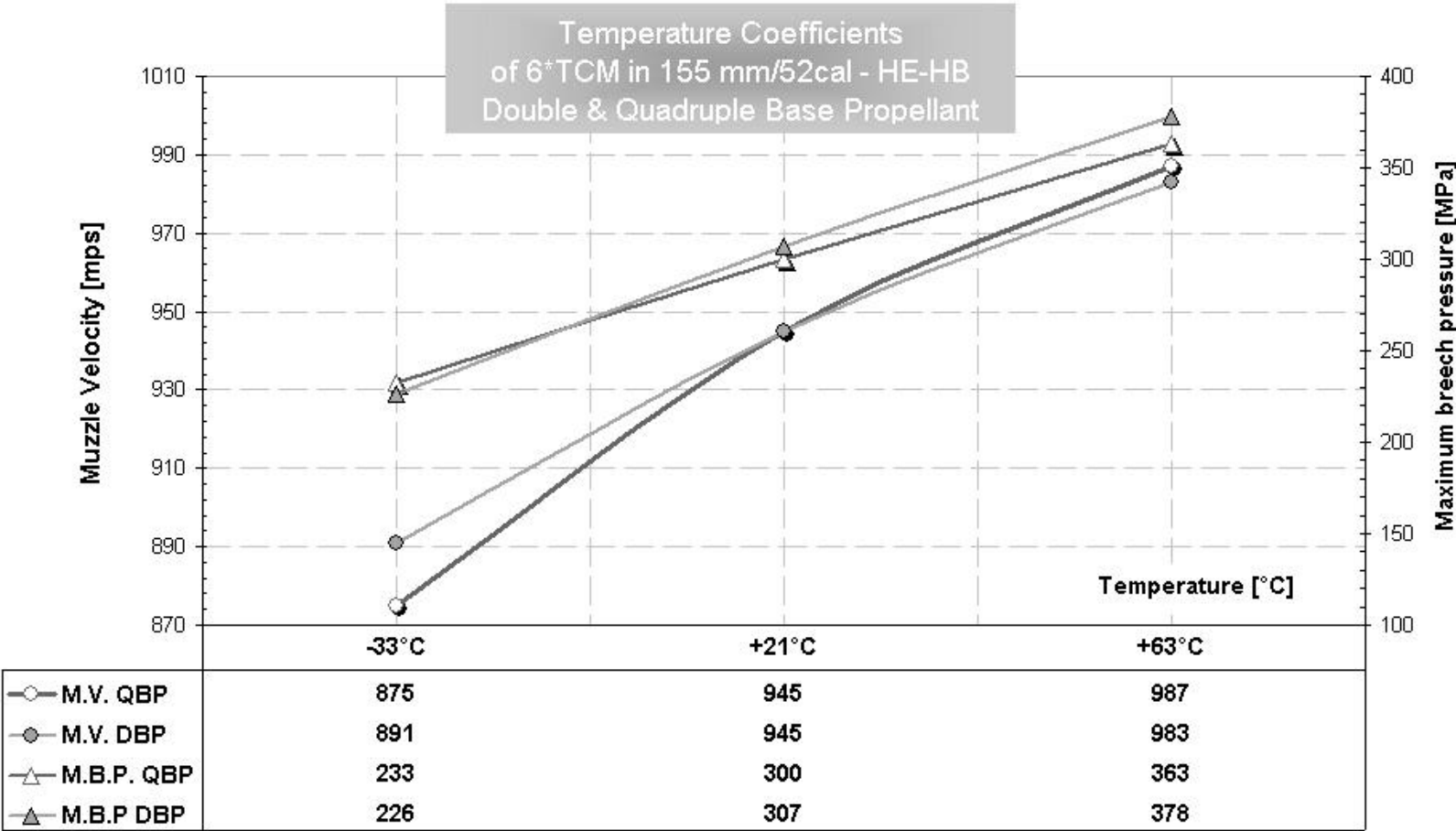
Gun propellant (web mm)	Kerf DB 19p (2.2)	Kerf QB 19p (2)	Kerf QB 7p (2.1)	Max value
Weight (kg)	13.02	13.89	14.05	
Loading ratio	0.92	1	0.96	< 0.98
SDMV (m/s)	2.5	1.3	0.8	1.6
Max pressure (Mpa)	342	341	336	

### At 63°C

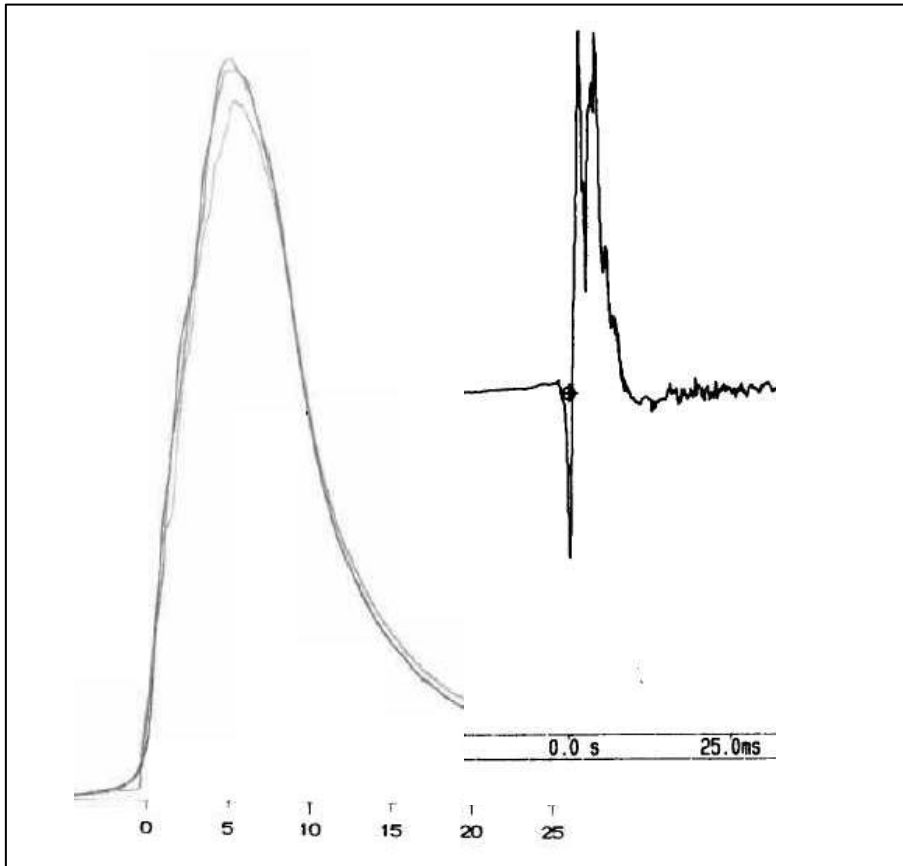
Max pressure (Mpa)	410	400	378	
MOP : max Pressure + 3 s P	430	416	390	406

QB propellant and 7 perf geometrie was selected for max pressure respect

# TCM temperature coefficient -gun propellant effect



## Firing test results in 155 52 calibres for 6 modules



P1 max 307.3 MPa

P2 max 302.5

P3 max 290.2

P1 - P3 max 36 MPa

P1 - P3 min - 16.3 MPa

	result	max value
(? P-) MPa	<-30	<-35
(? P- + ? P+) MPa	<70	<72.5

combinaison of kerfed sticks and axis  
free volum igniter lead to reduce  
pressure waves at zone 6

## TCM firing test results in 155 52 calibre for 6 modules

	Kerf DB 19p(2.2)	Kerf QB 19p(2)	Kerf QB 7p(2.1)	Max value
6 modules ignition delay to $\geq 25$ MPa (ms) 21°C	< 50 ms	< 50 ms	< 50 ms	300 - 15
6 modules ignition delay to $\rightarrow 25$ MPa (ms) - 33 °C	< 62 ms	< 62 ms	< 60 ms	300 - 15
6 modules muzzle pressure (MPa)	60 MPa	60 MPa	60 MPa	80 MPa
Flash	no	no NQ effect	no NQ effect	no

Each configuration lead to satisfy action time, muzzle pressure and flash requirements

## TCM firing test results in 155 52 calibre for 5 and 6 modules

155 52 calibre tube without Cr layer (5 shots)

	Kerf DB 19p(2.2)	Kerf Qb 19p(2)	Kerf QB 7p(2.1)	GrainsSB19p(2.4)	Max value
5 modules wear $\mu$ /shot max P (MPa) 21°C MV (m/s)	0.8 194 810	0.4 198 810			
6 modules wear $\mu$ /shot max P (MPa) 21°C MV (m/s)	6 360 955	8 341 946	7 336 946	5 361 948	1
6 modules wear $\mu$ /shot max P (MPa) 63°C MV (m/s)	9 405 975	11.7 400 983	11 378 980		

Wear increases a lot (x10) from 5M to 6M

Gun propellant composition can't reduce alone wear tube

Solution must come from anti wear agent putting in the charge or with tube coating

## TCM firing test results in 155 52 calibres for 3 modules

Gun propellant (web mm)	Kerf DB 19p (2.2)	Kerf QB 19p (2)	Kerf QB 7p (2.1)
21°C muzzle velocity (m/s)	532	532	
21°C max pressure (Mpa)	90	90	
-33°C muzzle velocity (m/s)	535	520	500
-33°C max pressure (Mpa)	80	80	82

These results with case composition within wear reduction show no residue in the chamber or tube after firing

## Vulnerability level for one TCM module

Complete module comprises:

2.4 kg gun propellant kerf QB 7p 1.9 mm NC/TEGDN/NQ/RDX: 52/26/9/11

0.23 kg CCC NC/kraft/resin: 68/26/5

0.03 kg black powder

Test	Ref STANAG	Result	Max value MURAT (*)
Fast cook off	4240	V 11s	IV
Slow cook off	4382	IV 129.3°C	III
Bullet impact	4241	IV/V	III
Sympathetic detonation	4396	III	III

Higher level requires containers for fast cook off delay requirement

Depending the logistic specification next step concerns the selection type of container

## TCM module mechanical withstanding



Complete module comprises:

Combustible container

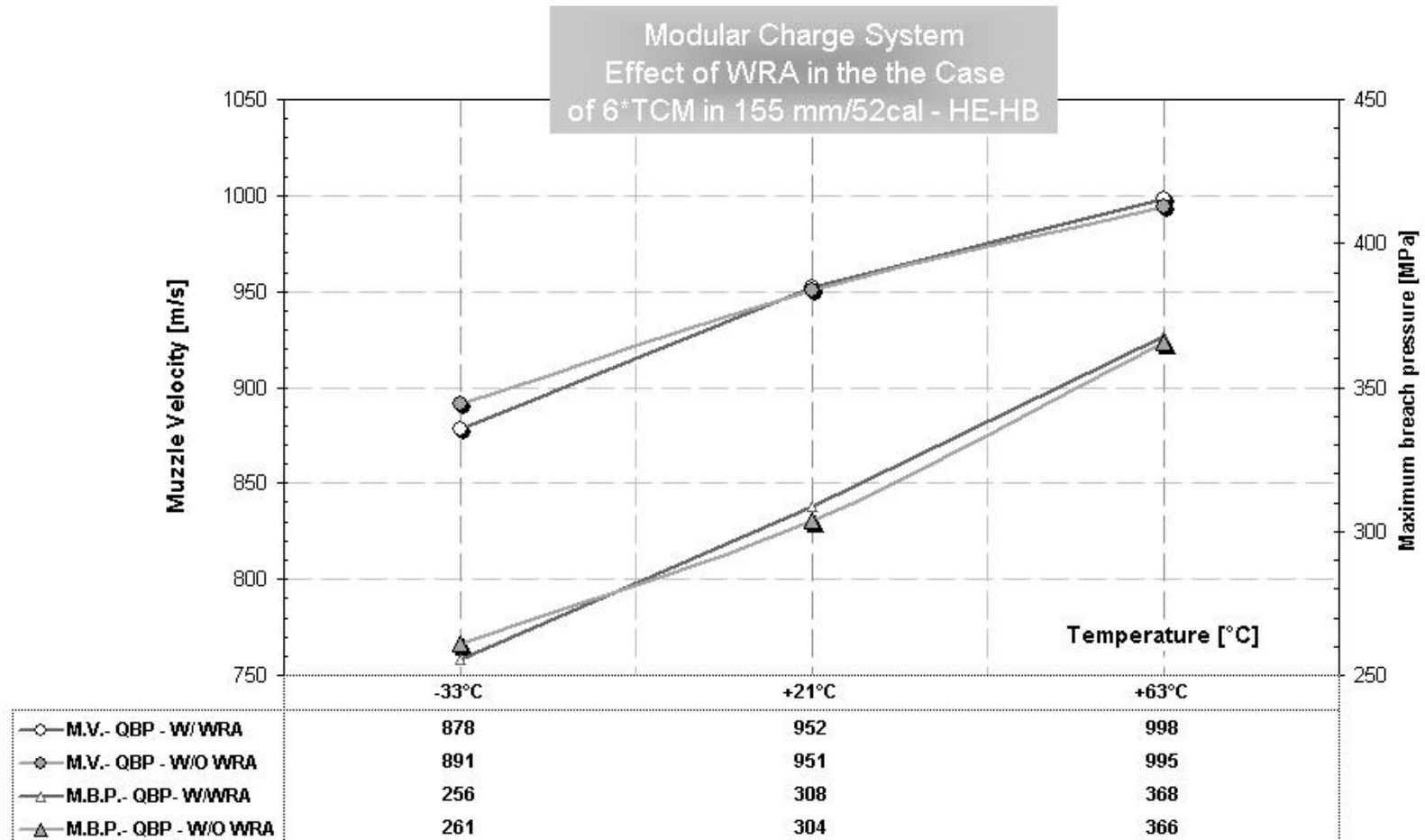
Real Igniter

2.500 kg propelling charge

		Combustible container	
Test		Without WRA	With WRA
Drop test STANAG 2914 - Bare module - 3 cumulative drops		OK 1.2 meter	OK 1.2 meter
Autoloader Turret 155 AuF2	Mechanical withstanding (both sides -reversibility)	OK Yes	OK Yes
155/52 CAESAR	Hooking in the chamber at any site angle Withstanding at breech impact	OK OK	OK OK
Loading in howitzerTR G2	Hooking in the chamber at any site angle Geometrical compatibility	OK Yes	OK Yes

**TCM modular charge reach the specifications for automated loading system**

## TCM temperature coefficient -case composition effect



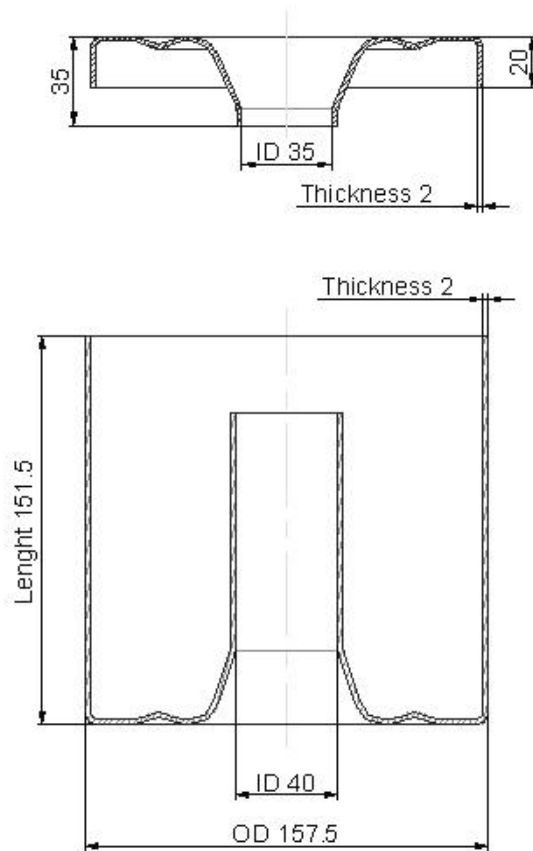
## TCM firing test results in 155 39 calibres for 3, 4 and 5 modules

Same charges lead to got at 21°C

Charge	Vo (m/s)	Max P (MPa)	? P-/? P+	Action time (ms)
5 M	812	280	-10/+20	100
39 cal Charge 7	797	294	-25/+30	
4 M	663	170	-5/+10	90
39 cal Charge 5	685	195	-20/+16	68
3 M	510	100	-2/+4	90
39 cal Charge 4	488	102	-5/+5	75

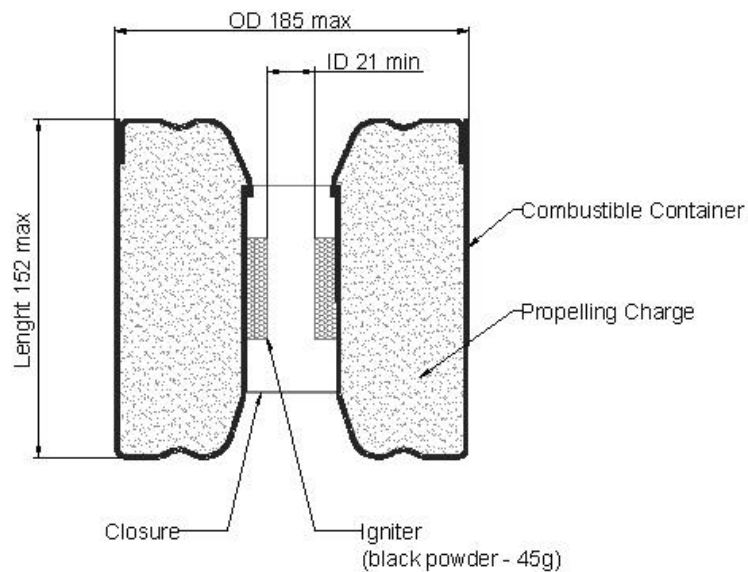
TCM charges results are close to existing bagged charges in 39 calibre gun , pressures waves levels are reduced

## BCM design - Combustible Container

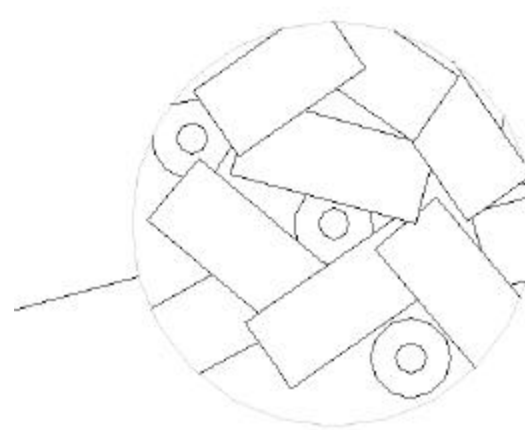


Composition of felted material	
Nitrocellulose	68 %
Cellulose	26 %
Resin binder	5 %
Stabilizer (DPA)	1 %

## BCM design - Propelling charge



Composition of igniter	
Consolidated Black powder	100 %
weight	45 g



### Composition of single base propellant

Nitrocellulose	93.7 %
Stabilizer (DPA)	1 %
Plasticizer (DBP)	4.5 %
Flash reducer	0.8 %

### Geometry of the grain



## TCM firing test results in 155 52 calibres for 1 and 2 modules

at 21°C

	1 M	2 M	Max value
Muzzle velocity (m/s)	305	462	
Max pressure (MPa)	61.2	171	
Action time (ms)	46	40	300 - 25

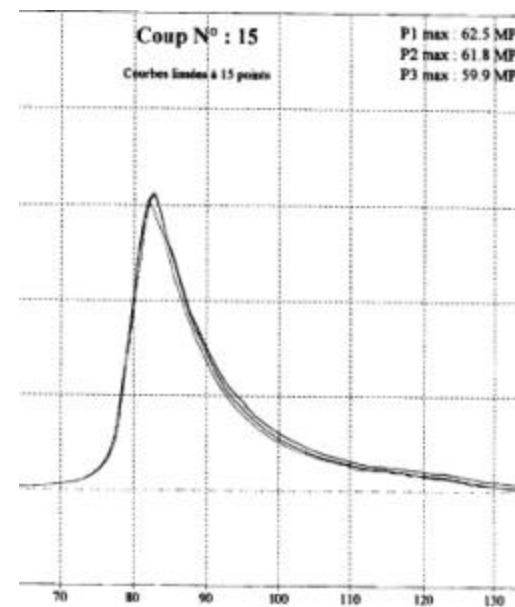
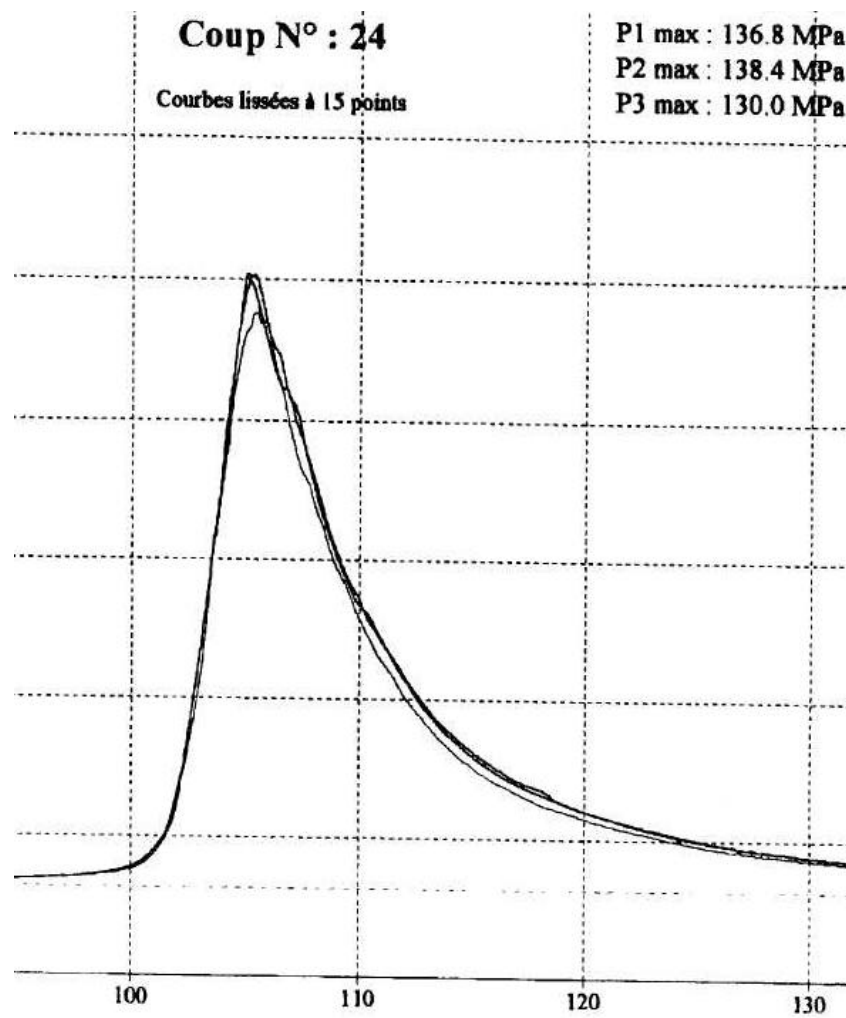
at - 33°C

	1 M	2 M	Max value
Muzzle velocity (m/s)	301	457	
Max pressure (MPa)	57	141	
Action time (ms)	81	65	300 - 25

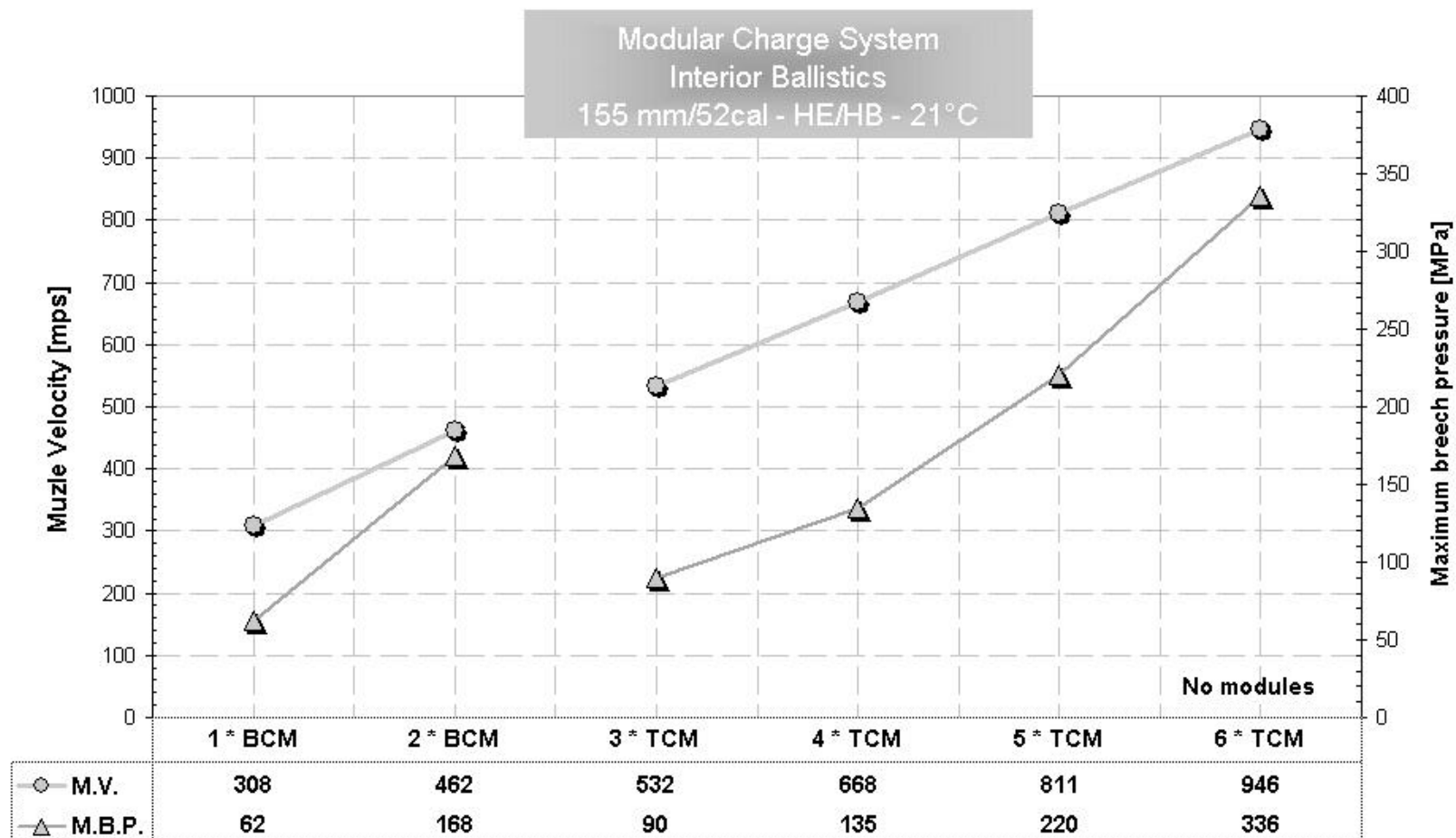
These results with case composition within wear reduction show no residue in the chamber or tube after firing

Temperature coefficient for pressure and velocity are low

## TCM firing test results in 155 52 calibres for 1 and 2 modules



## MCS - BCM and TCM Ballistic performances



## **French modular artillery BCM and TCM charge system for 155 mm**



### **Conclusion**

Tests performed both with BCM and TCM during the four years development at GIAT and SNPE of such new charges have permitted to demonstrate the capability of the design and the choice of the elements for new 155 mm calibre gun :

- gun propellant compositions and geometries
- combustible cases compositions, process and geometries
- igniters

This modular artillery charge system matches the NATO Joint Ballistic Memorandum of Understanding, it is fully interoperable with all NATO 155 mm ordnance including autoloader systems and in particular French CAESAR truck-mounted artillery system or the French 155 AUF2 self-propelled artillery system with fully automated handing and loading both for charge and shell.

This programme is a co-operative development by GIAT with SNPE as the main sub-contractor under a contract awarded by the DGA, the procurement agency of the French Ministry of Defence.